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Flathead Basin
Forest Practices,
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Cooperative
Program
Summary report

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FLATHEAD BASIN FOREST PRACTICES
WATER QUALITY AND FISHERIES
COOPERATIVE PROGRAM

SUMMARY REPORT

JUNE 1991

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About This Report

This report summarizes the conclusions and recommendations from the *Final Report* related to ten individual studies conducted for the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program. The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission.

The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variables relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances.

Contributors

U.S. Forest Service—Flathead National Forest
Plum Creek Timber Company, L.P.
Montana Department of State Lands Forestry Division
Water Quality Bureau of the Montana Department of Health and Environmental Sciences
Montana Department of Natural Resources and Conservation
University of Montana
- Flathead Lake Biological Station
- School of Forestry
- Montana Forest and Conservation Experiment Station
- U.S. Department of Agriculture—McIntire-Stennis Program

Montana Department of Fish, Wildlife and Parks
Flathead Basin Commission
Montana Environmental Quality Council
Montana Chapter of the American Fisheries Society
Governor's Office, State of Montana

Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program

Summary Report

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INTRODUCTION

Have forest practices impaired water quality and fisheries in the Flathead River Basin? And if they have, what changes in forest management should be made in the Flathead Basin in order to prevent or mitigate these effects?

To address these questions, the Department of State Lands, the Flathead National Forest, Plum Creek Timber Company, L.P., the Department of Fish, Wildlife and Parks, the Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission established the "Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program." They signed a "Memorandum of Understanding" in August of 1988. A Coordinating Team administered the Cooperative Program, scientific study leaders directed each specific project, and resource specialists from various organizations provided technical assistance as needed.

The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries.

This cooperative program included a variety of studies (modules). Some studies were conducted to obtain a better understanding of the overall interactions among forest practices, water quality, and fisheries. Other studies were direct approaches to evaluate and provide new information on management practices. A variety of research methods were used, including historical analysis of existing data, collection of new field data, field audits of management practices by teams of experts, formal summaries of expert opinion, field assessment of environmental conditions, experimental work, and evaluation of models.

Eight study leaders developed ten individual studies. They conducted these studies during 1989 and 1990. They held a coordination workshop early in 1989 to develop linkages among the studies and to obtain external review from three watershed and fisheries scientists living in Idaho and Washington. A set of study watersheds was selected at this workshop to help integrate as many of the field studies as possible.

The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variables relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables

influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances.

The studies were conducted in cooperation with the land managers and resource management agencies. However, every attempt was made to have the researchers maintain independence of analysis and interpretation of results. The organization of reports illustrates this process. The complete individual module reports stand alone as scientific documentation of findings of the individual studies. (These "stand-alone" reports are available through the Flathead Basin Commission, 723 Fifth Avenue East, Kalispell, Montana 59901.) The study leaders summarized their reports for inclusion in the *Final Report.* Then the study leaders individually drafted conclusions and recommendations as a basis for discussion and interaction.

The study team leaders held workshops during the spring of 1991 to review results and to develop a consensus set of summary conclusions and recommendations for consideration by the cooperating land management organizations. The land management organizations then developed a formal response to the recommendations for inclusion in the *Final Report.* Following final editing and printing, the *Final Report* will be presented at a summer workshop for public information and response.

This *Summary Report* includes the "General Discussion," "Summary of Conclusions," "Summary of Recommendations," "Response of Major Forest Land Managers to the 'Summary of Recommendations,'" "Memorandum of Understanding," and list of "Participants in the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Project."

General Discussion

The "Summary of Conclusions" that follows this section is organized according to the same major headings as used in the body of the report. Within those headings we have either brought forward the specific conclusions from individual modules or combined them where appropriate.

The "Summary of Recommendations" represents a consensus of the study team leaders related to the original objectives of the cooperative program. Total agreement could not be reached on all items. In these cases, we bowed to the lead investigator for that topic. We originally planned to present the recommendations in the same format as the rest of this report, but it didn't work well for making recommendations. Therefore, we organized the recommendations to start at the site where individual practices take place, move to the watershed level of cumulative effects, and then to the general water quality and fisheries concerns.

The land managers who are part of this cooperative were then asked to respond to the "Summary of Recommendations" with the intention that their responses would be published as part of this document.

The recommendations on monitoring are offered as suggestions to be considered also in the Flathead Basin Cooperative Monitoring Plan.

As is true in many studies, by the time the assigned work is completed, it becomes clear that additional questions were raised during the conduct of the study. Several of these are listed as suggested studies.

Some of the issues we addressed may require political decisions and a clear agreement among multiple landowners in the same watershed as to competing objectives and acceptable tradeoffs. Hopefully, we provided useful information to help make difficult decisions regarding the balance between competing and often overlapping socio-economic and socio-environmental concerns.

Summary of Conclusions

The following section represents a consensus of the study team leaders on the conclusions most relevant to the general objectives of the cooperative program. They are arranged in the same general order as the presentation of study modules.

Historical Record, Water Quality, and Fisheries

Changes in stream flow and the transport and deposition of fine sediments over the past 140 years were evaluated by examining two sources of historical records: mean daily discharge at stream gaging sites and sediment accumulation on lake bottoms. These evaluations indicated the following relationships between lake/stream measures and timber harvest, and other land use activities. Source module for each conclusion is identified as:

*A = Module A: An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records.

*B = Module B: Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments.

Historical Record

1. Comparison of spring runoff regimes among major river drainages in the Flathead between 1940 and present indicated that drainages having experienced extensive timber harvest also have spring runoff occurring earlier in the year than similar drainages having little timber harvest. (*A)
2. It appears that timber harvest may result in a higher peak in spring discharge during above normal runoff years, but not in major flood years. (*A)
3. Lake coring analyses indicated that past human land disturbance activities increased fine sediment deposition up to 10-fold in Whitefish Lake in the 1930s and 4- to 5-fold in Lake McDonald between 1930 and 1960. (*B)
4. Lake McDonald
   a. Initial road construction and upgrading of the Going to the Sun Road from Lake McDonald to the continental divide at Logan Pass during the 1930s and 1940s were accompanied by substantial increases in sediment deposition in Lake McDonald. (*B)
   b. After the road was paved in the early 1950s the sediment deposition rate in Lake McDonald returned to background levels and has remained at background levels over the last 25 years. (*B)

5. Whitefish Lake
   a. Large increases in sediment deposition occurred during the early part of this century (1900-1910) and were attributed to railroad construction along the lakeshore and logging activity around the lake. (*B)
   b. The largest sedimentation increases occurred in the early 1930s when substantial logging and associated road and rail line construction were concentrated in the Lazy Creek drainage and Lower Swift Creek, near the head of Whitefish Lake. (*B)
   c. Sedimentation rates also were elevated from the 1950s through the mid-1970s. These increases were attributed to substantial logging and associated road building activity, which extended to upper portions of the Whitefish Lake drainage. (*B)
   d. Recent logging activity in the Whitefish watershed was not accompanied by increased sedimentation in Whitefish Lake. Possible explanations for reduced sediment impacts include use of preexisting roads, logging on less-erodible lands, improved logging and road-building practices, and a series of comparatively mild runoff years. (*B)
6. Results from the two study lakes suggest that roads represent the greatest disturbance activity resulting in increased sediment transport and deposition in the downstream lakes. Once road surfaces stabilize (especially when paved), additional delivery of road-related fine sediment was not detected from sediment core analysis in McDonald Lake and road stabilization is probably also responsible for declining sediments in Whitefish lake. (*B)
7. Changes in lake sedimentation directly attributed to floods, fires, and other natural erosion processes during the past 150 years were much smaller than changes attributed to human disturbance activities in the two lake basins. Previous speculation that erosion of naturally unstable stream banks and other natural sources may mask sediment inputs attributed to human activities appear unfounded for the Whitefish Lake and Lake McDonald basins in light of data collected in the present study. (*B)

Water Quality and Fisheries

A broad array of streams in the Flathead Basin were evaluated by monitoring various physical, chemical, and biological variables and conducting controlled field experiments. Evaluated stream sites included watersheds with no timber harvest and no roads, no timber harvest with roads, and with timber harvest and roads. Among those watersheds with timber harvest and roads, stream sites were selected to represent different levels of percentage harvest within the basin. Source module for each conclusion is identified as:

*C = Module C: The Effect of Timber Management on Stream Water Quality.
*D = Module D: Fisheries Habitat and Fisheries Populations.

8. Monitoring data collected from this research indicated the following statistically significant relationships ($p < 0.1$, or better) between timber harvest activity (that is, road building, harvest, etc.) and several physical, chemical, or biological measures of stream ecosystem quality.
   a. Timber harvest activity was positively correlated with suspended sediment concentrations in streams. (*C)
   b. Timber harvest activity was positively correlated with concentrations of nutrients (nitrogen and phosphorus). (*C)
   c. Timber harvest activity was positively correlated with the percentage of fine sediment in trout spawning gravels. (*D)
   d. Timber harvest activity was positively correlated with gravel imbeddedness in streams. (*D)
9. Field surveys indicated the following statistically significant relationships (correlations analyses; $p < 0.1$, or better).
   a. Timber harvest activity was positively correlated with algal growth in the streams. (*C)
   b. Imbeddedness was negatively correlated with juvenile bull trout densities in streams. (*D)
   c. The mean percentage of fine sediments in spawning areas of undisturbed watershed streams in the Flathead Basin was 31.7% (range 24.8% to 39%) while in watersheds subject to timber harvest the mean percentage of fine material was 39% (range 32.8% to 50.3%). (*D)
10. Experimental studies showed that increases in the amount of fine sediment in spawning gravels caused a significant reduction in embryo survivorship of bull trout and westslope cutthroat trout. When the percentage of fine sediment reached

40%, survivorship of both species was reduced below 30%, and with 50% fine sediments, embryo survivorship was only 4%. (*D)

Stream Reach Assessment

The Water Quality Bureau's statewide nonpoint source stream reach assessments were conducted on 30 study streams containing 95 reaches. The qualitative visual survey results were evaluated by comparison with the results of the other modules. The source module for conclusions is identified as:

*E = Module E: Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin.

11. Tree blowdown (due to inadequate streamside management zones or prescription), sediment from poor road maintenance, logging slash in the stream channel, and bank trampling by livestock were observed by the surveyor to be the primary causes of stream problems related to management practices. (*E)
12. Quantitative fisheries study results that identified impairment to fish spawning or rearing habitat did not correlate well with impairment values derived from the assessment procedure. The assessments generally identified less impairment than the results from the fisheries study. This indicates that the assessment procedure either does not identify or underestimated impairment to beneficial uses. (*D and *E)

Forest Practices

Forest practices are often viewed as potential threats to water quality and fisheries. Direct measurement of nonpoint source pollution from specific practices is too costly to be used for routine evaluation on all activity areas. Therefore, the standard approach (accepted by the Environmental Protection Agency) for attempting to minimize nonpoint source pollution is to first develop a set of Best Management Practices (BMPs) based on research and experience, that will help protect water quality and beneficial uses. Field audits of BMP application and effectiveness are then used as an indirect evaluation.

The current procedure for evaluation of effectiveness is based on field review by experienced teams. BMPs are general

standards and often require site-specific interpretation. Concurrent studies have been underway to develop improved management guidelines for riparian/wetland habitat types as an aid to site-specific interpretations. This section reports the conclusions from those modules that were addressing forest practices at the site-specific level:

*F = Module F: Assessments of Best Management Practices.
*G = Module G: Management Guidelines for Riparian Forests.

13. BMPs are generally better-applied and more effective in the Flathead Basin than in the state in general. However, there is still considerable room for improvement in both application and effectiveness. (*F)
14. Audits revealed that the greatest number of departures were related to road drainage and road maintenance, followed by failure to recognize and modify practices in the SMZ. (*F)
15. A major value of the Audit process is the opportunity for education and improvement of communication. (*F)
16. Application of new "habitat type-specific" management information will be a valuable aid for site-specific evaluation and prescription. (*G)
17. New criteria will provide for consistent field delineation of Streamside Management Zones to meet the intent of the Best Management Practices. (*G)
18. An erosion risk matrix in relation to slope and soil erodibility is now available to estimate erosion hazards of different forest practices. It can be used for watershed-level risk assessment of proposed alternative practices (Module I), for future BMP evaluation (Module F), and for general interpretations. (*G)

Watershed Evaluation

One of the essential links in understanding the relations between forest practices and the aquatic ecosystem is the assessment of cumulative effects. Models to predict cumulative effects are still in the developmental stage. The R1–R4 Sediment Model and the H.0Y Water Yield Model have been the standard prototypes. Two alternative models (Sequoia and GIS Erosion Risk) were evaluated as a part of this program and a very recent model (WATSED) was also partially evaluated. The conclusions in this section are based on the following modules:

*H = Module H: Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin
*I = Module I: A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application
*J = Module J: Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data

19. The Sequoia methodology provides a straight-forward, simple accounting system for evaluating watershed disturbance related to water yield and a relative numerical rating. (*H)
20. Application of the Sequoia method in the Swan River Drainage demonstrated that a few analysis areas had an unusually high concentration of activities. (*H)
21. The Sequoia method results generally agreed with estimates of cumulative effects provided by other models. (*H)
22. Watershed erosion risk analysis may provide resource managers with a powerful tool to assist in land-use decision making. In addition, Geographic Information Systems allow the correlation of land cover and topographic information such as terrain configuration and drainage networks, thus making GIS useful in assessing the potential effects of land-use activities on water resources. (*I)
23. There was a statistically significant correlation between the change in Channel Stability Rating (CSR) and H_2OY water yield increase, Sequoia Cumulative Runoff Area (CRA), WATSED water yield increase, and WATSED water yield increase — 75 percent peak flow duration. (*J)
24. WATSED equivalent clearcut acreage was positively correlated with suspended sediment. (*J)
25. Three of the 30 watersheds selected for the correlation review were above the thresholds for both Sequoia and H_20Y, while 3 other watersheds with relatively high values for Sequoia had relatively low to moderate values for H_20Y. (*H and *J)
26. The correlation between the measured suspended sediment values and the predicted WATSED sediment values was highly significant. (*J)

Summary of Recommendations

The following recommendations have been developed through interaction by the module study leaders. The module summaries and the "Summary of Conclusions" section, presented earlier in this document, were organized in a format that proceeded from analysis of historical records, direct study of water quality and fisheries variables, auditing of adherence to Best Management Practices (BMPs), expert opinion to set riparian management guidelines, and evaluation of watershed risk analysis. This recommendation section is structured in two parts: Part I deals with forestry practices at the site level and evaluation of cumulative effects at the watershed level and Part II deals with general water quality and fisheries concerns.

Part I

Audits of Best Management Practices, Management Guidelines, Watershed Evaluations, and Use of Watershed Models and Inventories

Basis for Recommendations

No federal legislation has had greater significance for management of the environment than the National Environmental Policy Act of 1969 (NEPA). NEPA required federal agencies to evaluate "the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity" and "any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented." These evaluations, as they pertain to forest management, began the practice of Cumulative Watershed Effects (CWE) analysis.

Clearly, the best possible CWE analysis would be the actual measurement of changes in the environment. This is the role of monitoring and field research. Approximately half of the funds expended in this cooperative were devoted to that task. However, monitoring has limitations, among these are cost and time. Forest management takes place in thousands of watersheds of varying size and environmental sensitivity through the Flathead Basin. We simply cannot physically or financially afford to monitor all of these activities. This problem is not unique to the Flathead Basin. Consequently, a great deal of effort has gone toward developing alternative methods (or strategies) for both evaluating and preventing CWEs.

Modeling is one of the alternatives for CWE analysis and has been selected for use by the Flathead National Forest and the

Montana Cumulative Watershed Effects Cooperative. Watersheds are very complex and our modeling capabilities are limited. Furthermore we have little faith in model predictions largely because we have not tested our models by monitoring and field research. Again, these problems are not unique to the Flathead Basin. Consequently, other National Forest Regions have also adopted the more qualitative CWE "risk" assessment procedure approach. Recent development of Geographic Information Systems make application of these procedures easier and more comprehensive.

Section 319 of the Clean Water Act, added by amendment in 1987, requires states to establish Best Management Practices (BMPs) for the control of nonpoint sources of pollution (the form of pollution typically generated by forest management activities). BMPs are practices that are targeted to minimize the production of nonpoint source pollution, specifically organic and inorganic sediments, nutrients, and temperature. The State of Montana convened a group of resource specialists to compile Montana's BMPs — thus an expert opinion process. The BMPs have subsequently been approved by the Environmental Protection Agency, and at least for the time being remain voluntary for land managers in Montana (so long as they protect beneficial uses).

Best Management Practices have no value in protecting resources if they are not applied, are improperly applied, or are ineffective. Therefore, nearly every state involved with forest management, including Montana, has developed a process to audit BMPs in the field — another expert opinion "group-decision" process. The audit results generate a qualitative assessment as to whether BMPs have been implemented and evaluate their effectiveness in keeping sediment out of streams.

Nearly every BMP audit finds that the majority of problems result from roads and poor management in the Streamside Management Zone (SMZ). Road BMP criteria were not specifically studied in this cooperative program; however, SMZs were evaluated (Module G). Neither Montana's BMPs nor recent legislation (House Bill 731, Legislative Session 52) consider SMZs as areas of activity exclusion; but rather as areas of special consideration, equipment limitation, and especially careful management.

Riparian areas exhibit tremendous variation in characteristics and susceptibility to damage. There is little published research on management of Montana riparian forests. Consequently, managers have insufficient information or guidelines to help them make site-specific management prescriptions. The current lack of conclusive scientific data thus calls for the use of local experience and expert

opinion documented in the form of type-specific management guidelines.

The following recommendations regarding forest practices are primarily from:

Module E — Application of the Montana Nonpoint Source Stream Reach Assessment in the Flathead Basin,
Module F — Assessments of Best Management Practices, and
Module G — Management Guidelines for Riparian Forests.

The following recommendations regarding watersheds are primarily from:

Module H — Application of the Sequoia Method for Determining Cumulative Watershed Effects in the Flathead Basin,
Module I — A Forest Management Nonpoint Source Risk Assessment Geographic Information Systems Application, and
Module J — Linear Correlation/Regression Analysis of Forestry Models, Risk Assessment, and Water Quality and Fisheries Data.

Specific Recommendations

Forest Practices Recommendations

1. Acceptance and use of the State Best Management Practices is the first step toward ensuring that forest practices will not degrade water quality and fisheries. This will require unqualified commitment of large landowners and continual efforts to educate and encourage private landowners. The education efforts initiated by the Montana Logging Association must be expanded to reach small private landowners. If the "voluntary" system does not work and existing legal procedures are inadequate to ensure prompt action on reported violations, a mandatory system through a forest practices act should be enacted.
2. Land managers should utilize the new riparian habitat type classification and type-specific management information for

guidance in site-specific prescriptions.

3. Land managers should adopt the new streamside management zone criteria set by the Montana Riparian Association for consistent delineation and marking of streamside management zones.

Monitoring Forest Practices and/or Further Study Needs

4. Because of the demonstrated value of the audit process, it is recommended that the audits continue on an annual or biennial basis.
5. A cooperative study is needed to address the question of woody debris recruitment for maintaining stream integrity. Consideration needs to be given to inventory techniques for establishing current conditions, establishment of desired future conditions for different sizes and types of streams, appraisal of current streamside forest stand composition and structure, and the effects of different practices on ensuring the desired rate and amount of woody debris recruitment.
6. Because data are lacking on the hydrologic functioning of wetland sites, land managers will never have a comfortable basis for determining and defending reasonable access and practice standards. Therefore, managers and/or cooperative researchers should establish a program and monitor water table depths throughout the season and before and after logging on a set of representative riparian/wetland sites.
7. Qualitative evaluation of SMZ effectiveness relative to width and practices within the SMZ should be continued as part of the standard BMP audit process.

Watershed Evaluation Recommendations

8. We recommend testing the nonpoint source risk matrix assessment procedure in the Flathead Basin. In comparing the results with those of the other techniques, use GIS capabilities and the data sets obtained for the other watershed analyses conducted by the Cooperative.
9. We recommend adding the Sequoia procedure to the package of watershed assessment techniques — especially for application to watersheds that have a high level of activity and may be approaching "threshold" levels of activity concerns.
10. Further study is needed to improve watershed prediction models so that they become more reliable for assessing probable cumulative effects of a range of practices for a range

of site conditions.

11. A great opportunity exists for the design of monitoring activities within a framework of cooperative research management to provide definitive results for the calibration models. We recommend that this opportunity not be bypassed.
12. Watershed level analysis and planning to address cumulative effects and scheduling of activities should be standard practice. Cooperative planning and coordination of activities should become a standard practice in all mixed-ownership drainages.
13. The Montana Water Quality Bureau nonpoint source stream reach assessment procedure (Montana Water Quality Bureau 1989) should not be relied upon to identify problem areas relative to the forest practices/water quality and fisheries issue in Flathead Basin.
14. Further analysis and interpretation is recommended for the selected study streams.

Part II Historical Perspective, Water Quality, and Fisheries

Basis for Recommendations

During the initial meetings of this Cooperative, land managers stated that they had seen little or no quantitative evidence that past timber management practices had resulted in significant degradation of water quality and fisheries in the Flathead Basin. We discussed that natural sediment loadings and variability in the Flathead Basin may be so high that increases attributable to timber management activities may be difficult to detect. Land managers stated, "we want to know, one way or the other, if past activities have had an impact on water quality and fisheries in the Flathead Basin." Therefore, one of the primary objectives of this Cooperative was to gather quantitative data to address this question.

Analysis of data collected in the historical record, water quality, and fisheries research modules reveal that timber harvest activities have resulted in: (1) changes in the spring runoff pattern, (2) increased sediment loading in streams and lakes, (3) increased nutrient loading to streams and lakes (since sediments represent a signifi-

cant source of nutrients), (4) increased attached algae biomass in streams (algal growth responds to increased nutrients), (5) increased percentage of fine sediments in trout spawning gravels, and (6) increased substrate imbeddedness. The largest source of sediments appears to be from new road construction and subsequent existence of unstable roads. (Supporting evidence from the BMP audits in Module F revealed that the greatest number of departures were related to road drainage and road maintenance, followed by failure to recognize and modify practices in the SMZ.)

Increased sediment and nutrient loadings represent significant threats to streams and lakes in the Flathead Basin (as discussed in Modules B, C, and D). Streams may be altered by such increases that affect their food webs and habitats. (See Module C.) Past studies have shown that sediments likely represent the single largest source of phosphorus to most lakes in the Flathead Basin. (See Module B.) Erosion and transport of sediments and nutrients in streams, as a result of land use activities, have undoubtedly contributed to lake eutrophication. This undesirable process results in stimulation of algal growth, reduced water clarity, oxygen depletion, and other problems. At present, important lakes in the Flathead Basin (including Flathead Lake and Whitefish Lake) are on a threshold (for references see Module B), such that further increases in nutrient loading seriously threaten their water quality. Considerable efforts are being made to reduce point-source input of nutrients in the Flathead Basin. This has been done in an attempt to maintain the high water quality that characterizes many lakes in the basin. Such efforts include construction of multi-million dollar advanced wastewater treatment plants in all major communities above Flathead Lake. Similar efforts should be directed at other significant controllable nutrient sources in the basin, including land disturbance activities documented in our studies and elsewhere.

Because of their value as a sport fishery, increasing rarity across their native range, and as indicators of high water quality, both bull trout and westslope cutthroat trout have been designated as sensitive species by the U.S. Forest Service, and "Species of Special Concern" by the State of Montana. Field evidence indicates that juvenile bull trout densities decrease in streams having high substrate imbeddedness. Also, experiments of egg hatching and embryo emergence (one of the most sensitive stages of the salmonid life cycle) of bull trout and westslope cutthroat trout reveal a direct negative relationship between embryo survivorship and the percentage of fine sediment in spawning gravels. Many key spawning streams already

are at, or near, the threshold whereby increased levels of fine sediments in spawning gravels will greatly reduce embryo emergence of bull trout and westslope cutthroat trout. Further study may be required to verify these relationships in areas outside the Flathead Basin.

The following recommendations are an integration of the Historical Perspective:

Module A — An Analysis of the Effect of Timber Harvest on Streamflow Quantity and Regime: An Examination of Historical Records and

Module B — Evaluation of Historical Sediment Deposition Related to Land Use through Analysis of Lake Sediments.

and the Water Quality and Fisheries:

Module C — The Effect of Timber Management on Stream Water Quality and

Module D — Fisheries Habitat and Fish Populations.

Specific Recommendations

Historical Perspective, Water Quality, and Fisheries Recommendations

15. Increase efforts toward continued improvement of timber harvest practices, road building, and road maintenance to prevent undesirable increases in erosion, sediment transport, and nutrient loadings to surface waters in the Flathead Basin.
16. At present most timber base lands in the Flathead Basin contain a network of roads, some of which are maintained for use, and others which have been abandoned. Past construction and use of roads appears to be the most significant human disturbance activity associated with timber management that has contributed to sediment delivery to streams and lakes in the Flathead Basin. Therefore we recommend the following:
    A. Evaluate the existing road system and ameliorate those roads and associated cut slopes that are known to contribute sediment or pose a potential threat to contributing sediment to surface waters in the Flathead Basin. Strong consideration should be given to road surfacing and cut-slope stabilization on high risk roads, trunk roads designated for long-term use, and roads in the

immediate vicinity of streams.

B. Minimize new road construction and limit construction of new roads to areas of the basin where the risk of increased sediment delivery to surface waters is low. Ensure use of BMPs and mitigation measures with the goal of eliminating undesirable sediment delivery associated with new road construction.

17. Bull trout and westslope cutthroat trout, Species of Special Concern in Montana, are native to the Flathead Basin. Both species are highly valued sport fishes that are very sensitive to degradation of spawning and rearing habitats resulting from increased sediment delivery to streams. Therefore we make the following recommendations:

A. Obtain information on fish species composition in drainages where management activities are planned and current status is unknown.

B. ***Bull Trout:*** Continue monitoring or begin monitoring streams having known bull trout spawning and rearing areas. A listing of these streams is available from the Montana Department of Fish, Wildlife and Parks.

i. ***Threatened Streams.***

When the following stream criteria are met,

- the percentage of fine materials in spawning gravels in any given year is greater than 35% and/or
- the substrate score (measure of imbeddedness) is less than 10,

the stream is considered threatened as a bull trout spawning and/or rearing stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take active precautions to minimize new sediment loading to the stream.

b) Steps also should be taken to ameliorate past roading or other human land disturbances that continue to contribute sediments to streams.

ii. ***Impaired Streams.***

When the following stream criteria are met,

- the percentage of fine materials in spawning gravels in any given year is greater than 40% and/or
- the substrate score (measure of imbeddedness) is less than 9,

the stream is considered impaired as a bull trout spawning and/or rearing stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take pro-active steps to insure that no additional sediment loading occurs as a result of new land disturbance activity.

b) Stabilize all existing problem roads and/or past activities which are continuing to deliver sediment to streams.

C. ***Westslope Cutthroat Trout:*** Continue or begin monitoring Flathead Basin streams having known areas of concentrated spawning by migratory westslope cutthroat trout. At present, the Montana Department of Fish, Wildlife and Parks has identified eight such streams in the basin.

i. ***Threatened Streams.***

When the following stream criterion is met,

- the percentage of fine materials in spawning gravels in any given year is greater than 35%,

the stream is considered threatened as a westslope cutthroat trout spawning stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take active precautions to minimize new sediment loading to the stream.

b) Steps also should be taken to ameliorate past roading or other human land disturbances that continue to contribute sediments to streams.

ii. ***Impaired Streams.***

When the following stream criterion is met,

- the percentage of fine materials in spawning gravels in any given year is greater than 40%,

the stream is considered impaired as a westslope cutthroat trout spawning stream.

If any disturbance activity is planned in the watershed, the land owner should:

a) Take pro-active steps to insure that no additional sediment loading occurs as a result of new land disturbance activity.

b) Stabilize all existing problem roads and/or past activities which are continuing to deliver sediment to streams.

D. Streams not supporting bull trout spawning and/or rearing or concentrated westslope cutthroat trout spawning.
   i. There is currently insufficient data to establish thresholds for unacceptable percentages of fine material in spawning gravels used by fish species other than bull trout and westslope cutthroat trout. Therefore, we recommend further study of sediment effects on the fish species found in these streams.

18. Ensure strict adherence to BMPs by regular inspection during harvest/site preparation activities followed by monitoring field audits on sales located in watersheds meeting criteria for threatened or impaired bull trout or cutthroat trout streams.
19. Conduct a two- to three-day symposium/workshop during spring 1992 at the Flathead Lake Biological Station to specifically address innovative means of timber harvest, road building, and other timber transport methods that may be used in the Flathead Basin with the goal of eliminating sediment delivery to surface waters. The product of the workshop should be testable hypotheses that may be used in a series of "Demonstration Projects" accompanied by effective cooperative scientific study and monitoring of sediment routing and delivery, and other key water quality and fisheries parameters. For example, a demonstration project might be to quantitatively test the effectiveness of specific BMPs, road paving, cable logging, etc., by pre- and post-activity monitoring of various water quality and fisheries parameters in adjacent surface waters. Such monitoring would fall under the short-term monitoring effort described below.

Monitoring and Additional Study Needs of Stream Water Quality and Fisheries

In 1985 the Flathead Basin Commission (FBC) adopted a water quality and fisheries *Monitoring Master Plan*. The comments and recommendations for monitoring or further study are made within the context of that *Master Plan*.

We recommend that two types of water quality and fisheries monitoring sites be established — long-term sites and short-term sites. These are summarized briefly here.

Long-term monitoring should have the purpose of establishing baseline conditions and evaluating long-term changes that may be masked over short time periods by interannual variation. These long-term monitoring stations should be representative of the

various dominant physical/geological conditions of the land and with various levels and types of management activity. Long-term monitoring should be conducted on a routine, non-intensive basis. Monitoring parameters should consist of stream discharge, routine nutrients, sediments, and other basic water chemistry parameters, as well as fisheries variables. Data from the long-term monitoring stations could also be used for validation of various models used to assist land managers in decision making.

Short-term monitoring should have the purpose of monitoring specific activities. Short-term monitoring stations should change through time with a comparatively short time frame of commitment to any particular site. Short-term monitoring sites should have a multi-year lifetime, beginning two years before the activity, one year during the activity, and two years after the activity. Data from short-term monitoring stations may also be used for model validation, BMP effectiveness monitoring, Demonstration Project evaluation, or evaluation of other proposed forest practice changes designed to reduce impacts on water quality.

With the large amounts of money spent on monitoring, a great opportunity exists to design monitoring efforts so they can be used to test research hypotheses as well as accomplish monitoring goals. These efforts should be developed in concert with the following specific monitoring and study recommendations which were taken from the individual study modules. They are ***not*** listed by order of preference or priority.

20. We recommend that lake basins supporting future, long-term timber harvest and road building activities have a monitoring program designed to document the impact of these activities on lake water quality. Current water quality monitoring efforts in the Flathead Basin are focused primarily on Flathead Lake and tributary streams. However, there are a number of smaller lake basins in the area which support significant timber harvest activities but have little water quality monitoring information. Lakes in this category which are valued for their water quality and/or fisheries resources include Swan, Whitefish, Ashley, Lake Mary Ronan, and others. **We urge immediate emphasis on Swan Lake** given the recent evidence of oxygen depletion in the lake together with extensive land use activities in the basin. Monitoring efforts should include a combination of in-lake monitoring for documentation of lake conditions as well as upstream monitoring to document various source areas including site

specific inputs from new activities in the basin.

Monitoring activities should include establishment of sediment and nutrient budgets for the basin (for nonpoint sources as well as point sources such as septic systems and wastewater effluent), Secchi depth transparency, phytoplankton abundance (chlorophyll-a in the lake), as well as dissolved oxygen and temperature profiles. We recommend that serious consideration be given to analysis of additional sediment cores from Swan Lake as well as a sediment core from Bowman Lake which has had no human land disturbance activity. In addition, we recommend development of some simple sediment accumulation monitors (traps) that could be placed at key locations in Swan Lake and other lakes of interest. These collection devices would serve as continuous monitors of sediment delivery into the lake environment. Annual monitoring of sediment accumulation in these traps over a period of years would yield extremely valuable information concerning changes in sediment and nutrient loadings. These data should be integrated with continuous monitoring of sediment in the streams (see Recommendation No. 31).

21. Additional sediment core analysis in Whitefish Lake, focusing on sediments deposited in the last 30 years, would provide a better understanding of the relative importance of the various factors which could explain the recent reduction in lake sedimentation rate. Sediment core sampling increments of one year or less would allow more definitive conclusions to be drawn about BMP effectiveness. In order to evaluate the potential impact of recent mild runoff years on sedimentation rates, it would be useful to collect additional cores from Whitefish Lake following several high runoff years.
22. Expansion of sediment core analyses to other lakes would expand the applicability of conclusions, which at this point come from three lakes in the Flathead Basin. We highly recommend collection of sediment cores from a "control" lake which has had no human disturbance (for example Bowman Lake in Glacier National Park). Other candidate lakes include those found in watersheds supporting past and future logging efforts such as Tally, Ashley, and Flathead Lakes.
23. Lake sediment analyses should be integrated with surface water monitoring and nutrient analysis to provide more in-depth linkages between sediment and nutrient loadings.

24. Develop a basin-wide stream classification system that integrates geomorphology and selected current physical, chemical, and biotic criteria (for example, number of bull trout stream segments, base flow nutrient concentrations).
25. Adjust the FBC *Monitoring Master Plan* to reflect evaluation of cause-and-effect relationships between forest practices such as BMPs and selected water quality variables.
26. Algal growth should be used as a monitoring tool of timber harvest impact and evaluation of BMPs.
27. Macroinvertebrates have been shown elsewhere to be an excellent indicator of stream ecosystem degradation. Although we found no significant relationships in this study between timber harvest and invertebrate community attributes, we believe that this is because the study streams selected for investigation are not sufficiently impaired to result in quantifiable species losses. Therefore, macroinvertebrate studies should be tailored to document severe stream ecosystem damage on a site-by-site basis.
28. Recruitment of woody debris to streams is known to be important to maintaining stream ecosystem character with natural pool-to-riffle ratios, retention of organic matter, retention of sediment, and fish migratory, spawning, and resident fish habitats. However, we do not know the effect of past practices or the possible effect of proposed SMZ management on this important stream attribute. Thus, we recommend that a study be undertaken to determine the frequency distribution and effect of woody debris on the Flathead Basin streams. Additional SMZ research was also recommended in Module G.
29. Continue monitoring fish populations and habitat conditions in Flathead Basin tributaries. Adjust the FBC *Monitoring Master Plan* to reflect continued evaluation of cause-and-effect relationships between forest practices, fish populations, and fish habitat.
30. Use McNeil coring to monitor spawning/incubation habitat in important spawning areas identified in the FBC *Monitoring Master Plan*. However, use caution to ensure that the sediment disturbance caused by the monitoring efforts themselves does not negatively impact spawning areas.
31. Extend efforts to develop a Whitlock-Vibert box sampling program for the Flathead Basin. If this methodology can be validated, it will reduce stream disturbance caused by McNeil

coring and provide greater flexibility and expansion of monitoring of the percentage of fine sediment in stream substrates.

32. Continue to monitor substrate scoring in all streams identified as critical rearing habitat for juvenile bull trout.
33. Continue to monitor fish population on streams supporting bull trout. Continue to develop similar estimation/habitat relationships for other species, particularly indices which correlate population densities of westslope cutthroat trout.
34. Expand the fisheries sampling program to a greater number of known high risk watersheds.

Response of Primary Forest Land Managers

The Flathead National Forest, Montana Department of State Lands, and Plum Creek Timber Company, L.P., are three of the major forest land managers in the Flathead Basin and were the original sponsors of this study. We recognize the importance of maintaining water quality and fisheries and will continue to give these valuable resources the attention they deserve. It is important to recognize that we as professional land managers are charged with the responsibility of managing other resources in addition to water and fisheries — for example, wildlife, timber, recreation, grazing, air quality, minerals, oil and gas, aesthetics, etc. Our challenge is to ensure a balanced management approach for all resources. We agree in concept with the "Summary of Recommendations" and offer the following comments on them.

Forest Practice Recommendations

The managers recognize that the implementation of effective Best Management Practices (BMPs) is required to ensure that the effects of forest practices are minimized. We are all involved in a continuing effort to educate our land managers and all landowners and logging contractors on the benefits associated with the effective use of BMPs.

The Flathead National Forest uses riparian habitat types to design projects associated with riparian areas. The other land managers agree in concept to the use of this classification in future project design. The passage of Montana House Bill 731 will provide mandatory regulations governing the conduct of forest practices within streamside management zones.

Monitoring Forest Practices Recommendations

Internal BMP audits are being conducted on all lands by the respective land managers. We recognize the value of continuing the cooperative interdisciplinary BMP audit program. We agree with the need to develop prescriptions for woody debris recruitment to provide for fish habitat and channel stability. House Bill 731 authorizes the Montana Department of State Lands to establish an interdisciplinary technical committee to assist in the development of rules and guidelines to protect the integrity of streamside management zones. The managers intend to have representatives on the technical committee and assist in the development of appropriate rules and guidelines.

Watershed Evaluation Recommendations

Each of the managers is a member of the Montana Cumulative Watershed Effects Cooperative (MCWEC). The goal of this cooperative is to share information and technology, including the use of WATSED as the primary watershed model in an effort to address the issue of cumulative effects. The studies did not show that the Sequoia model was more accurate than WATSED, and a change to the Sequoia model is not planned.

The MCWEC's members annually provide each other with their plans for roading and timber harvest. Cooperators are then in a position to undertake watershed planning and cumulative effects analysis. The managers encourage continuing close coordination of these complex issues.

Water Quality and Fisheries Recommendations

The land managers acknowledge the significance of bull trout and westslope cutthroat trout as "Species of Special Concern" which are sensitive to sedimentation of their habitat. We will cooperate in obtaining more complete information on the distribution of these species and the condition of their habitats. Also, we will continue to support efforts to understand habitat relationships for all fish species which may be affected by forest practices.

The MCWEC provides an excellent forum for the exchange and discussion of fisheries information as it relates to management activities. This process would be greatly strengthened by increased participation from the Montana Department of Fish, Wildlife and Parks. As a starting point, the Department of Fish, Wildlife and Parks should provide a list of bull trout and westslope cutthroat trout streams they consider threatened or impaired.

In recent years, more attention has been focused on eliminating or controlling sediment delivery to streams from management activities. Efforts should continue to improve forest practices to reduce erosion and transport of sediment and nutrients to surface waters. We will emphasize this objective as a crucial step in the protection of water quality and fish habitat.

The land managers will strive to maintain a transportation system which has as little impact on water quality as possible. We recognize that reducing erosion on existing roads is desirable, especially during spring runoff. We will continue to correct problems created by past road construction. Where new road construction occurs, the land managers will take all reasonable and effective measures to reduce erosion and sediment loads. We will continue to maintain existing roads to minimize erosion and employ the most

appropriate BMPs available when constructing new roads. We will also continue the Montana Road Management Cooperative, which is providing significant benefits to both wildlife and water quality through road closures.

Most known bull trout spawning areas and some identified westslope cutthroat trout spawning areas in watersheds with timber management allocations are presently being monitored. There are other streams used by fewer bull trout which spawn over a more dispersed area, and many more streams where cutthroat spawning sites are likely to be scattered along considerable stream length. Monitoring all these streams, sites would have to be arbitrarily chosen, especially if spawning areas have not been identified or change annually. Given the reality of limited budgets, monitoring efforts must be focused on streams which could be affected by management activities, plus a sampling of some natural or "control" streams.

We have concerns about using a highly-impactive sediment sampling technique in smaller streams that have a limited supply of spawning gravel. Continuous monitoring could result in net loss of spawning habitat.

The studies indicate that sediment levels have a critical effect on developing trout. These results provide a basis for assessing habitat conditions and will undoubtedly influence management decisions regarding future road construction and timber harvest. An inherent problem with the use of threshold sediment values is the fact that there is a wide range of natural variability in streams with respect to flows and sediment. In cases where lakes or streams are classified "threatened" or "impaired," increased concern is justified. In these situations, we will comply with the special recommendations to control erosion, protect water quality, and maintain fish habitat.

Difficult questions remain regarding applicability of the recommendations to westslope cutthroat trout streams. Additional monitoring of westslope cutthroat trout spawning areas must be undertaken with caution to avoid habitat degradation. Selecting spawning areas to monitor may be arbitrary in many streams. Random samples of potential spawning gravel do not provide a definitive description of habitat condition or population status for westslope cutthroat trout.

It must be recognized that watersheds are complex and dynamic systems. Most of the variation in aquatic habitat condition was not correlated with upland management activities. Consequently, it should not be assumed that constraints on roading and logging will

protect or improve native fisheries in all cases. More effort to develop streamflow and sediment routing relationships is needed so that upland activities and changes in streambed materials can be better understood.

Although we realize that determination of limiting factors for local trout populations was beyond the scope of this study, the issue is an important one. The study results show that sediment alone does not regulate fish abundance in the Flathead Basin. Nevertheless, we accept our responsibility to ensure that forest practices do not degrade fish habitat.

Monitoring and Additional Study Needs

Water quality and fisheries monitoring recommendations have been developed and carried out according to the Flathead Basin Commission Monitoring Master Plan. Land managers agree in concept with the "monitoring and additional study needs." Revisions to the Master Plan should reflect the recommended changes. Water quality and fisheries habitat monitoring are high priority programs. However monitoring must be balanced within budget constraints and within the framework of other management objectives and priorities.

These studies were valuable in providing a focus on the relationships between forest practices, water quality, and fisheries. We appreciate the time and effort that has gone into this comprehensive evaluation and believe it will contribute to the maintenance of high water quality standards in the Flathead Basin.

Joel Holtrop — 5/9/91
Joel Holtrop
Supervisor
Flathead National Forest

W.J. Parson — 5/14/91
W.J. Parson
Director of Operations, Rocky Mountain Region
Plum Creek Timber Company, L.P.

Gary G. Brown — 5/14/91
Gary G. Brown
State Forester
Montana Department of State Lands

APPENDIXES

Appendix A:

Memorandum of Understanding

Between
Flathead Basin Commission
Montana Department of State Lands
Plum Creek Timber Company, Inc.
Flathead National Forest
Montana Department of Health and Environmental Sciencies
Montana Department of Fish, Wildlife & Parks
University of Montana

July 1988

This MEMORANDUM OF UNDERSTANDING is made and entered into by and among the Flathead Basin Commission, hereinafter referred to as FBC; Montana Department of State Lands, hereinafter referred to as DSL; Plum Creek Timber Company, Inc., hereinafter referred to as PCTCI; Flathead National Forest, hereinafter referred to as FNF; Montana Department of Health and Environmental Sciences, hereinafter referred to as DHES; Montana Department of Fish, Wildlife & Parks, hereinafter referred to as FWP; and the University of Montana, hereinafter referred to UM.

* * * * *

In the Flathead Basin, one third of the watershed is composed of forested lands which are managed for commercial forest production by FNF, DSL, PCTCI, and other entities. Valuable commodities are produced that substantially contribute to the regional economic base.

Flathead Lake and its tributary streams and rivers host water quality and a fishery of superlative quality which offers a valuable economic and recreational resource.

The effects of certain forestry activities (e.g., logging and associated road construction) may be a potential risk to the aquatic environment. At this time, the cause-and-effect relationship of specific forest practices on water quality and fisheries is not known.

WHEREAS, FBC is a legislatively created body to address the Flathead Basin's aquatic environment, the waters that flow into or out of Flathead Lake, and other resources of the Basin; and

WHEREAS, DSL and FNF are government agencies that manage commercial forest lands within the Flathead Basin; and

WHEREAS, PCTCI is a private enterprise which owns and manages commercial timberlands; and

WHEREAS, DHES is charged with enforcing the laws governing water quality in the state of Montana; and

WHEREAS, FWP is charged with managing the fisheries resource of Montana; and

WHEREAS, UM is an institution of higher education providing teaching, research, and service for the benefit of Montana citizens and resources,

THEREFORE, in consideration of the above, the parties agree to create and participate in the FLATHEAD BASIN FOREST PRACTICES/

WATER QUALITY AND FISHERIES COOPERATIVE PROGRAM, dated July 1988, hereinafter known as the Cooperative Program, as follows:

1. To fulfill the Specific Objectives of the Cooperative Program which are to document, evaluate, and monitor whether forest practices effect water quality and fisheries within the Flathead Basin and to establish a process to utilize this information, if detrimental impacts exist, to develop criteria and administrative procedures for protecting water quality and fisheries.

2. To follow the Purpose of the Cooperative Program which is to improve the management of Flathead area forested watersheds through the development and application of state-of-the-art information to prevent or mitigate the potential adverse effects of forest practices on water quality and fisheries.

3. To work closely and cooperatively as the Coordinating Team of the Cooperative Program to review and approve study elements so that the entire Cooperative Program forms a coherent package of studies and monitoring directed at learning if and how forestry activities affect fisheries and water quality.

4. To work closely as the Coordinating Team with the FBC on the logistics of the studies, funding and public participation.

5. Agree to reach decisions within the Coordinating Team by consensus.

6. The Coordinating Team will serve to review progress, offer suggestions, and facilitate appropriate assistance from resource specialists from the various organizations involved in timber management and oversight in the Flathead Basin.

7. The participants of the Cooperative Program will provide staff support, technical expertise, funding, and/or other in-kind assistance. The FNF, State of Montana, and PCTCI tentatively will make the following funds available to finance administrative studies:

	CY 1988	CY 1989	CY 1990
Flathead National Forest	$30,000	$50,000	$50,000
State of Montana, Renewable Resource Development Grant	-0-	$25,000[1]	$25,000[2]
Plum Creek Timber Co, Inc.	$10,000	$20,000	$20,000

[1] applied for
[2] estimated from other state of Montana sources

The indicated funds will be made available and are the maximum amount that each source will contribute in any one calendar year. The funds will not be considered obligated until the necessary procurement documents are completed.[3]

8. Study leaders of individual study modules will prepare annual work plans to be approved by the Coordinating Team but will otherwise operate independently of the Coordinating Team.

9. Progress of study modules will be reviewed by the Coordinating Team through annual work plans and semi-annual progress reports by the Study Leaders to the Coordinating Team.

10. This agreement shall become effective on the date of the last signature and continue for a period of three years from that date.

11. This agreement may be amended at any time with 60 days notice to the other parties. Amendments will require signatory approval by all the parties involved. Termination can be initiated by any one party.

* * * * *

[3] Nothing herein shall be construed as obligating the Forest Service to expend or as involving the United States in any contract or other obligation for the future payment of money in excess of appropriations authorized by law and administratively allocated for this work.

This MEMORANDUM OF UNDERSTANDING is agreed to by:

Executive Director
Flathead Basin Commission — 8/9/88 Date

State Forester
Department of State Lands — 8/8/88 Date

Director of Operations
Plum Creek Timber Company, Inc. — 8/8/88 Date

Supervisor
Flathead National Forest — 8/18/88 Date

Director
Department of Health and
Environmental Sciences — 8/9/88 Date

Supervisor
Region One
Department of Fish, Wildlife & Parks — 8/29/88 Date

Vice President for Research
University of Montana — 8/8/88 Date

APPENDIX B:

PARTICIPANTS IN THE FLATHEAD BASIN FOREST PRACTICES/ WATER QUALITY AND FISHERIES PROGRAM

Participants in the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program

Steering Committee

Loren Bahls, Supervisor, Water Quality Management Section, Montana Department of Health and Environmental Sciences, Helena, Montana

Edgar B. Brannon, Past Supervisor, Flathead National Forest, Kalispell, Montana and Past Chairman, Flathead Basin Commission

Gary G. Brown, State Forester, Forestry Division, Montana Department of State Lands, Missoula, Montana

Allen A. Elser, Past Regional Supervisor, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana

Joel Holtrop, Supervisor, Flathead National Forest, Kalispell, Montana

Glenn Marx, Executive Director, Flathead Basin Commission, Helena, Montana

Raymond C. Murray, Vice President of Research, University of Montana, Missoula, Montana

William Parson, Director of Operations, Rocky Mountain Region, Plum Creek Timber Company, L.P., Columbia Falls, Montana

Dan Vincent, Regional Supervisor, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana

Study Leaders

John Fraley, Past Fish and Wildlife Program Officer, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana

F. Richard Hauer, Ph.D., Research Associate Professor, Flathead Lake Biological Station, Polson, Montana

Robert Pfister, Ph.D., Research Professor, School of Forestry, University of Montana, Missoula, Montana

Don Potts, Ph.D., Professor, School of Forestry, University of Montana, Missoula, Montana

Dean Sirucek, Forest Soil Scientist, Flathead National Forest, Kalispell, Montana

Craig N. Spencer, Ph.D., Research Assistant Professor, Flathead Lake Biological Station, Polson, Montana

Steve Tralles, Environmental Specialist, Water Quality Bureau, Montana Department of Health and Environmental Sciences, Helena, Montana

Thomas Weaver, Research Specialist, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana

Technical Representatives

Larry Brown, Forest Hydrologist, Plum Creek Timber Company, L.P., Columbia Falls, Montana

Mike Enk, Forest Fisheries Biologist, Flathead National Forest, Bigfork, Montana

Bill Schultz, Hydrologist, Forestry Division, Montana Department of State Lands, Missoula, Montana

Dean Sirucek, Forest Soil Scientist, Flathead National Forest, Kalispell, Montana

Reviewers

Pete Bisson, Ph.D., Fisheries Scientist, Weyerhauser Company Technical Center, Tacoma, Washington

John G. (Jack) King, Ph.D., Research Hydrologist, Intermountain Research Station, U.S. Forest Service, Boise, Idaho

Dale McGreer, Resource Hydrologist and Lands Manager, Potlatch Corporation, Lewiston, Idaho

Coordinators

Craig Hess, Past Public Information Officer, Flathead Basin Commission, Kalispell, Montana

Mark Holston, Public Information Officer, Flathead Basin Commission, Kalispell, Montana

Dean Sirucek, Forest Soil Scientist, Flathead National Forest, Kalispell, Montana

Editor/Desktop Publisher

Katherine Althen, Consultant, Althen Associates, Kalispell, Montana

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